

533 Rec'd PCT/PTO 18 SEP 2001

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| FORM PTO-1390<br>(REV. 5-93)  |  | U.S. DEPARTMENT OF COMMERCE<br>PATENT AND TRADEMARK OFFICE |  | ATTORNEY'S DOCKET NUMBER<br>10191/1958                |  |
| TRANSMITTAL LETTER TO THE UNITED STATES<br>DESIGNATED/ELECTED OFFICE (DO/EO/US)<br>CONCERNING A FILING UNDER 35 U.S.C. 371  |  |  |  | U.S. APPLICATION NO. (If known, see 37 CFR 1.5)       |  |
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| INTERNATIONAL APPLICATION NO.<br>PCT/DE00/00754   |  | INTERNATIONAL FILING DATE<br>(10.03.00)<br>10 March 2000   |  | PRIORITY DATE CLAIMED:<br>(18.03.99)<br>18 March 1999 |  |
| TITLE OF INVENTION<br>ELECTROCHEMICAL GAS SENSOR  |  |  |  |   |  |
| APPLICANT(S) FOR DO/EO/US<br>STANGLMEIER, Frank; SCHUMANN, Bernd; MOSER, Thomas   |  |  |  |   |  |
| Applicants herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information  |  |  |  |   |  |
| 1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.<br>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.<br>3. <input checked="" type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).<br>4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.<br>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))<br>a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).<br>b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau.<br>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US)<br>6. <input type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2))<br>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))<br>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).<br>b. <input type="checkbox"/> have been transmitted by the International Bureau.<br>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.<br>d. <input checked="" type="checkbox"/> have not been made and will not be made.<br>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).<br>9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unsigned).<br>10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)). |  |  |  |   |  |
| Items 11. to 16. below concern other document(s) or information included:   |  |  |  |   |  |
| 11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.<br>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.<br>13. <input type="checkbox"/> A <b>FIRST</b> preliminary amendment<br><input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment<br>14. <input type="checkbox"/> A substitute specification.<br>15. <input type="checkbox"/> A change of power of attorney and/or address letter.<br>16. <input checked="" type="checkbox"/> Other items or information: PCT/RO/101.  |  |  |  |   |  |

U.S. APPLICATION NO. If known, see 37 CFR 1.5

INTERNATIONAL APPLICATION NO.

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PCT/DE00/00754

ATTORNEY'S DOCKET NUMBER

10191/1958

- 17.
- ☒
- The following fees are submitted:

**Basic National Fee (37 CFR 1.492(a)(1)-(5)):**

Search Report has been prepared by the EPO or JPO ..... \$860.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) ... \$690.00

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) ..... \$710.00

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$1,000.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) ..... \$100.00

CALCULATIONS | PTO USE ONLY

**ENTER APPROPRIATE BASIC FEE AMOUNT =**

\$ 860

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e))

\$

Claims

Number Filed

Number Extra

Rate

Total Claims

11 - 20 =

0

X \$18.00

\$ 0

Independent Claims

1 - 3 =

0

X \$80.00

\$ 0

Multiple dependent claim(s) (if applicable)

+ \$270.00

\$

**TOTAL OF ABOVE CALCULATIONS =**

\$ 860

Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).

\$

**SUBTOTAL =**

\$ 860

Processing fee of \$130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)).

\$

**TOTAL NATIONAL FEE =**

\$ 860

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property

\$

**TOTAL FEES ENCLOSED =**

\$ 860

Amount to be:

refunded \$

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a. ☐ A check in the amount of \$\_\_\_\_\_ to cover the above fees is enclosed.b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of \$860.00 to cover the above fees. A duplicate copy of this sheet is enclosed.c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.By Richard L. Mayer (Reg. No. 22,490)Richard L. Mayer

SIGNATURE

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9/18/01

DATE

PCT Rec'd 04 JUN 2002

[10191/1958]

## ELECTROCHEMICAL GAS SENSOR

The present invention relates to an electrochemical gas sensor for determining the concentration of oxidizable gas components in gas mixtures according to the generic part of Claim 1.

## 5 Background Information

From German laid-open document DE-OS 23 04 464 an electrochemical gas sensor is known, in which an electrode made of gold or silver is provided, which does not catalyze the establishment of equilibrium of the gas mixture, and which acts together with an electrode made of platinum which catalyzes the establishment of equilibrium in the gas to be measured (the measuring gas). The catalytically inactive electrode materials have the effect that, between the oxygen and the oxidizable or reducible gas components, respectively, a competitive reaction takes place at the electrode. Even with adjusted high lambda values, this causes the free oxygen carried along in the measuring gas hardly to react with, for example,  $C_3H_6$  or CO, so that free oxygen as well as  $C_3H_6$  or CO, respectively, reach the three-phase boundary at the catalytically inactive electrode. However, such a gas sensor has a considerable cross sensitivity to the oxygen also present in the gas mixture.

## 25 Summary of the Invention

The gas sensor according to the present invention, having the characterizing features of Claim 1, has the advantage that the cross sensitivity to oxygen can be reduced by pumping in oxygen. A further advantage is that a base sensor element,

which is fully developed from a manufacturing technique point of view, can be used, which has only to be changed by a modification of the electrodes. A so-called broadband sensor is used as base sensor element for determining the oxygen concentration, and it includes a pumping cell and a concentration cell (measuring cell), whereby a mixed potential sensor having a series-connected oxygen pumping cell is formed. The use of a base sensor element that is fully developed from a manufacturing technique point of view offers considerable cost advantages compared to sensor element construction which is specialized for each case of application.

As a result of the measures specified in the dependent claims, advantageous further refinements and improvements of the sensor element, indicated in the main claim, are possible. The cross sensitivity to oxygen can be reduced to the utmost if the partial pressure of the oxygen, which can be set in the gas to be analyzed by the pumping cell, has a lambda value of  $\geq 1.3$ .

#### Brief Description of the Drawing

An exemplary embodiment of the present invention is represented in the drawing and explained in detail in the following description. The Figure shows a cross-section through a sensor element of the gas sensor according to the present invention.

#### Exemplary Embodiment

The Figure shows a planar sensor element 10 of an electrochemical gas sensor, which, for example, has a plurality of solid electrolyte carrier layers 11a, 11b, 11c, and 11d that conduct oxygen ions. In this context, the solid electrolyte carrier layers 11a through 11d are designed as ceramic foils, and form a planar ceramic body after sintering.

The integrated form of the planar ceramic body is produced in a known manner, by laminating together the ceramic foils printed over with functional layers and subsequently sintering the laminated structure. Each of the solid electrolyte carrier layers 11a through 11d is formed from solid electrolyte material, conducting oxygen ion, such as  $ZrO_2$  stabilized with  $Y_2O_3$ .

Sensor element 10 has an electrochemical pumping cell 12 and an electrochemical measuring cell 13 (concentration cell) as well as a resistance heater 14. The resistance heater 14 is situated between solid electrolyte carrier layers 11c and 11d, and is embedded in electrical insulation 15, e.g. made of  $Al_2O_3$ . Sensor element 10 is heated to the appropriate operating temperature of, e.g.  $500^\circ C$ , by resistance heater 14.

Pumping cell 12 has an outer pumping electrode 16 and an inner pumping electrode 17. Measuring cell 13 is formed having a measuring electrode 18 and a reference electrode 19. The outer pumping electrode 16 is covered with a porous protective layer 21 and exposed to the gas to be measured. The inner pumping electrode 17 of pumping cell 12 and measuring electrode 18 of measuring cell 13 are located opposite each other in a measuring gas compartment 22 which is in communication with the gas to be measured via a gas access hole 23. Reference electrode 19 is located in a reference gas channel, which is in communication with a reference gas, such as air.

A porous diffusion barrier 25 is arranged inside measuring gas compartment 22, in front of inner pump electrode 17 and measuring electrode 18, in the diffusion direction of the measuring gas. Porous diffusion barrier 25 constitutes a diffusion resistor with regard to the gas diffusing towards electrodes 17, 18.

The described design of sensor element 10 corresponds to a so-called broadband sensor for determining the lambda value in

gas mixtures of  $\lambda < 1$  through  $\lambda > 1$ . In the broadband sensor, all electrodes are made of a material which catalyzes the establishment of equilibrium of the gas mixture, such as platinum and platinum cermet material.

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In the gas sensor of the present invention, which responds to oxidizable gases such as HC, H<sub>2</sub>, CO and NH<sub>3</sub>, in contrast to the broadband sensor mentioned, at least measuring gas electrode 18 positioned in measuring gas compartment 22 is made of a material which cannot or cannot completely catalyze the establishment of equilibrium of the gas mixture. Such a material, for example, is gold or a gold-platinum alloy, the gold proportion of the platinum-gold alloy being 0.5 to 20 weight-%, preferably 10 weight-%. These materials guarantee that measuring electrode 18, positioned in measuring gas compartment 22, is selective with respect to the oxidizable gas components contained in the gas mixture.

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In addition to measuring electrode 18, it is expedient to make the further inner pumping electrode 17, positioned in measuring gas compartment 22, likewise of a material which cannot, or cannot completely catalyze the establishment of equilibrium of the gas mixture. Inner pumping electrode 17 contains a platinum-gold alloy having a gold proportion of 0.1 through 3 weight-%, preferably 0.3 through 0.8 weight-%.

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A further requirement is that the materials be co-sinterable, that means, that they withstand sintering temperatures, such as 1400° C, required for sintering solid electrolyte carrier layers 11a to 11d. For producing a firm layer bond between solid electrolyte carrier layers 11a to 11d and electrodes 17, 18, the latter, as also electrodes 16, 19 are made of a cermet material. Aside from the catalytically active platinum or the catalytically inactive gold or platinum-gold alloy, such cermet electrodes contain a ceramic proportion corresponding in an advantageous way to the material of the adjoining solid electrolyte carrier layers 11a to 11d.

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In the operating method of the gas sensor, a pumping voltage is applied to pumping electrodes 16, 17 which is poled, according to the partial pressure of the oxygen, in such a way that, when there is a high oxygen partial pressure in the exhaust gas, oxygen is pumped out of measuring gas compartment 22, and when there is low oxygen partial pressure in the measuring gas, oxygen is pumped into measuring gas compartment 22. For this purpose, a corresponding switching arrangement is provided, which, in addition, guarantees that an essentially constant partial pressure of oxygen is maintained in measuring gas compartment 22.

Tests have shown that the cross sensitivity of the sensor to oxygen is low when there is a partial pressure of oxygen of  $\lambda \geq 1.3$  in measuring gas compartment 22, i.e., at measuring electrode 18. It was determined that with a partial pressure of oxygen of more than  $\lambda \geq 1.3$ , the influence of the oxygen concentration on the measuring result for determining the concentration of hydrocarbons is negligible. It is essential to the method of operation of the gas sensor for determining hydrocarbons that measuring electrode 18 is a so-called mixed potential electrode, which catalyzes no, or at least no complete establishment of equilibrium of the gas mixture. Together with reference electrode 19, positioned in reference gas channel 27, measuring electrode 18 forms a so-called mixed potential sensor, which is particularly used for determining carbohydrates.

The material of measuring electrode 18, which does not, or not completely catalyze the establishment of equilibrium, has the effect that a competing reaction takes place at measuring electrode 18 between the oxygen contained in the gas mixture and the reduced gas components, the carbohydrates carried along in the gas to be measured hardly reacting with the free oxygen. In the case of a catalytically active electrode, a reaction of the carbohydrates with the oxygen would take place. But to prevent this is the aim of the not catalytically

active mixed potential electrode. As a result, both the free oxygen and the carbohydrates reach the three-phase boundary of measuring electrode 18. At reference electrode 19, on the other hand, along with the reference air there is a constant, high partial pressure of oxygen.

At measuring electrode 18, the adsorbed carbohydrates now react, and a potential difference develops between measuring electrode 18 and reference electrode 19, which can be read off as electromotive force (emf) by a measuring instrument (not shown). Thus the emf depends on the concentration of the carbohydrates contained in the gas mixture. When there is a high concentration of carbohydrates, there is a high potential difference, and thus a high emf. When there is a low concentration of carbohydrates, the potential difference between measuring electrode 22 and reference electrode 19 is lower, and as a result, the generated emf is lower too.



What is claimed is:

1. An electrochemical gas sensor for determining the concentration of oxidizable gas components in gas mixtures, which has an electrochemical measuring cell (13) having a measuring electrode (18) and a reference electrode (19), the measuring electrode (18) being made of a material that is not able, or is not able to completely catalyze the establishment of gas equilibrium, wherein, additionally, at least one electrochemical pumping cell (12), having at least one inner pumping electrode (17), is provided, which, together with the measuring electrode (18), is positioned in a measuring gas compartment (22), the pumping cell (12) pumping oxygen into or out of the measuring gas compartment (22).
2. The gas sensor as recited in Claim 1, wherein an at least approximately constant partial pressure of oxygen can be set in the measuring gas compartment using the pumping cell (12).
3. The gas sensor as recited in Claim 1 or 2, wherein the partial pressure of oxygen which can be set in the measuring gas compartment (22) using the pumping cell (12) corresponds to a lambda value of  $\geq 1.3$ .
4. The gas sensor as recited in Claim 1, wherein the measuring electrode (18) and the inner pumping electrode (17) are positioned opposite each other in the measuring gas compartment (22).
5. The gas sensor as recited in Claim 1 or 4, wherein the measuring electrode (18) contains gold or a platinum-gold alloy.
6. The gas sensor as recited in Claim 5, wherein the gold proportion in the platinum-gold alloy of

the measuring electrode (18) is 0.5 to 20 weight-%, preferably 10 weight-%.

7. The gas sensor as recited in Claim 1 or 4, wherein, in addition to the measuring electrode (18), the inner pumping electrode (17) is made of a material which is not able, or not completely able to catalyze the establishment of gas equilibrium.
8. The gas sensor as recited in Claim 7, wherein the inner pumping electrode (17) contains a platinum-gold alloy having a gold proportion of 0.1 to 3 weight-%, preferably 0.3 to 0.8 weight-%.
9. The gas sensor as recited in Claim 1, wherein the reference electrode (19) is made of a material which is able to catalyze the establishment of gas equilibrium.
10. The gas sensor as recited in Claim 9, wherein the catalytically active material is platinum.
11. The gas sensor as recited in Claim 1, wherein the measuring gas compartment (22) is positioned in one layer plane, and a gas access hole (23) leads to the measuring gas compartment (22).

## Abstract

An electrochemical gas sensor is proposed for determining the concentration of oxidizable gas components which has an  
5 electrochemical measuring cell (13) having a measuring electrode (18) and a reference electrode (19). Measuring electrode (18) is made of a material which is not able, or not completely able to catalyze the establishment of gas  
10 equilibrium. In addition to the electrochemical measuring cell (13), at least one electrochemical pumping cell (12), having at least one inner pumping electrode (17), is provided, which, together with measuring electrode (18), is positioned in a measuring gas compartment (22). Oxygen is pumped into or out  
15 of measuring gas compartment (22) by pumping cell (12), the partial pressure of oxygen in measuring gas compartment (22) being set to a lambda value of  $\geq 1.3$ .

20 (Figure)

PCT

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Internationales BüroINTERNATIONALE ANMELDUNG VERÖFFENTLICHT NACH DEM VERTRAG ÜBER DIE  
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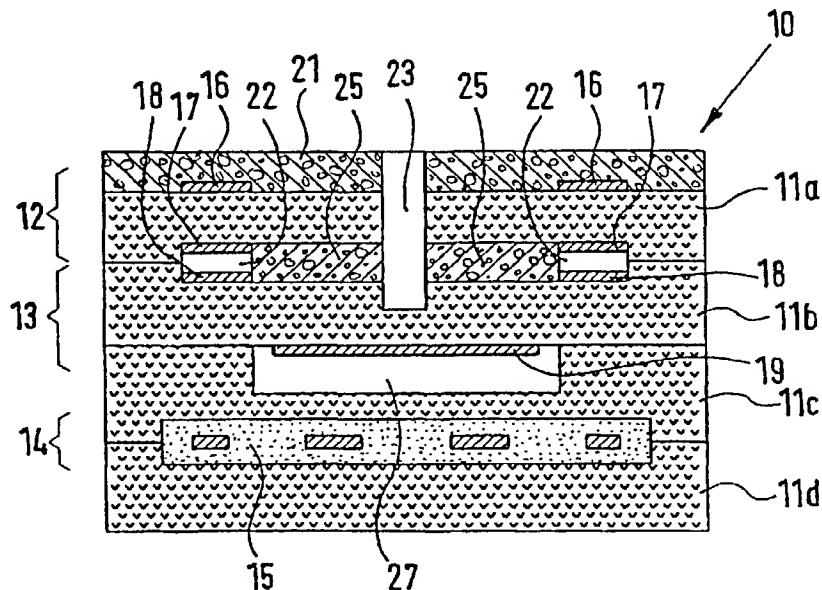
Mit internationalem Recherchenbericht.

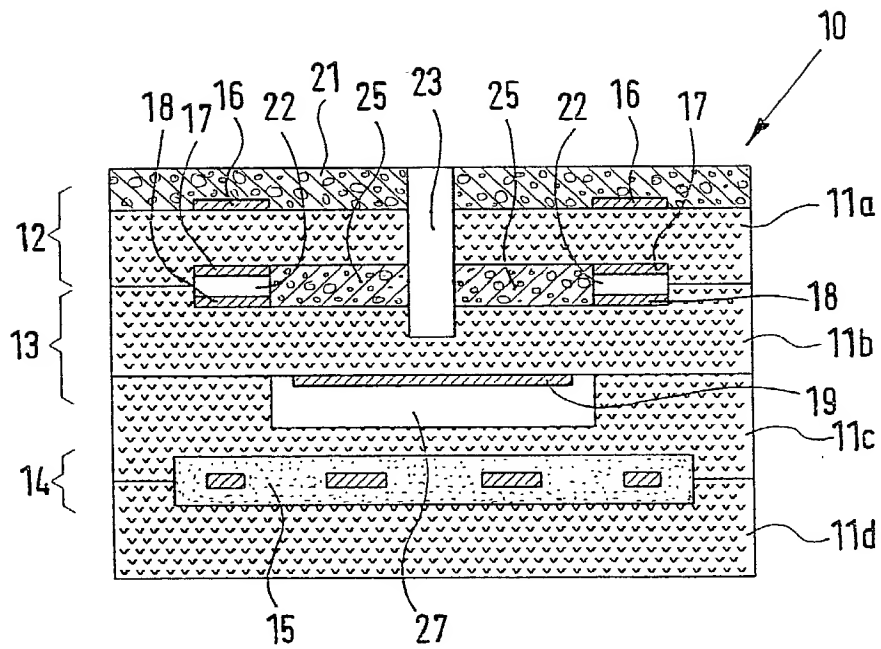
(54) Title: ELECTROCHEMICAL GAS SENSOR

(54) Bezeichnung: ELEKTROCHEMISCHER GASENSOR

(57) Abstract

The invention relates to an electrochemical gas sensor for determining the concentration of oxidizable gas components, comprising an electrochemical measuring cell (13) with a measuring electrode (18) and a reference electrode (19). Said measuring electrode (18) is made from a material that cannot or cannot fully catalyse the regulation of the gas equilibrium. At least one electrochemical pump cell (12) with at least one inner pump electrode (17) is provided in addition to the electrochemical measuring cell (13), said electrochemical pump cell being located in a measuring gas chamber (22) together with the measuring electrode (18). Oxygen is pumped into or out of the measuring gas chamber (22) by the pump cell (12), the partial oxygen pressure in the measuring gas chamber (22) being regulated to a Lambda value of  $\geq 1,3$ .





[10191/1958]

**DECLARATION AND POWER OF ATTORNEY**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **ELECTROCHEMICAL GAS SENSOR**, the specification of which was filed as International Application No. PCT/DE00/00754 on March 10, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

**PRIOR FOREIGN APPLICATION(S)**

| Number       | Country<br>Filed        | Day/Month/Year | Priority Claimed<br>Under 35 USC 119 |
|--------------|-------------------------|----------------|--------------------------------------|
| 199 12 100.1 | Fed. Rep. of<br>Germany | 18 March 1999  | Yes                                  |

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Gerard A. Messina (Reg. No. 35,952) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

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